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FRAMEWORK FOR MEASURING URBAN ENERGY SECURITY: CITIZEN PERSPECTIVE

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Abstrak. Konsumsi energi perkotaan yang terus meningkat menjadi isu penting dari ketahanan energi perkotaan. Warga berperan penting dalam membentuk konsumsi energi. Oleh karena itu, perspektif warga dapat memberikan dampak signifikan terhadap evaluasi ketahanan energi perkotaan. Penelitian ini bertujuan untuk memberikan kerangka kerja sistematis untuk mengukur ketahanan energi perkotaan dengan mempertimbangkan perspektif warga dan menunjukkan implementasinya di kota Bandung. Pendekatan sistem diadopsi untuk membangun kerangka pengukuran. Pendekatan ini menggunakan sudut pandang *top-down* dan *hierarhcycal* dalam membangun sebuah sistem. Kerangka yang diusulkan melalui 5 tahapan proses, yaitu (1) membangun konteks perkotaan, (2) mendefinisikan ketahanan energi yang relevan dengan konteks, (3) menentukan dimensi keamanan energi, (4) menentukan indikator dan dan metrik, dan (5) tahap terakhir adalah menghitung ketahanan energi. Kasus implementasi menunjukkan ketahanan energi di Kota Bandung berada pada status *Middle Low*. Hal inI juga memverifikasi bahwa kerangka kerja yang telah dibuat layak secara operasional dan dapat menangkap pentingnya perspektif warga.

Kata kunci: Bandung; kerangka pengukuran; ketahanan energi; urban; warga negara

[Title: Measuring Urban Energy Security: Citizen Perspective]. The ever increasing urban energy consumption has always been an important issue of urban energy security. Citizen plays critical role in shaping the energy consumption. Therefore, citizen perspective can give significant impact to urban energy security evaluation. This research aims to provide a systematic framework to measure urban energy security taking into account the perspective of citizen and showcase its implementation in a case of Bandung city. System approach is adopted to develop the framework. This approach take top-down and hierarchycal view on developing a system. The proposed framework is a straight five stages process as follow (1) establishing the urban context, (2) defining energy security relevant to the context, (3) determining dimensions of energy security, (4) determining indicators and and metrics, and (5) the final stage is calculating energy security. The implementation case shows Bandung's energy security is at Middle Low status. It also verify that the framework is operationally viable and it can capture the significance of citizen perspective.

Keywords: *citizen; Bandung; energy security; measurement framework; urban*

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1. INTRODUCTION

The ever increasing energy consumption in urban areas due to socio economic development has been the source of pressure on energy security. Urban energy consumption contributes for more than 60% of world energy consumption (Hoornweg et al.). It is expected that the contribution will be higher in the future as 62% of world population is estimated to be in urban areas in 2035 (International Energy Agency, 2013).

However, traditionally energy security has been measured mostly at country or regional level (Almeida Prado et al., 2016; Fang, Shi, & Yu, 2018; Greene, 2010; Hu & Ge, 2014; Jääskeläinen,

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Höysniemi, Syri, & Tynkkynen, 2018; Kanchana & Unesaki, 2015; Kharlamova, Stavytskyy, & Chernyak, 2018; Kumar, 2016; Lisin, Strielkowski, Chernova, & Fomina, 2018; Löschel, Moslener, & Rübbelke, 2010; Martchamadol & Kumar, 2012; Narula & Reddy, 2016; Radovanović, Filipović, & Pavlović, 2017; Von Hippel, Suzuki, Williams, Savage, & Hayes, 2011; Watson & Scott, 2009; Yao & Chang, 2014). This is mainly due to the fact that decisions and policies related to energy supply, such as energy resources and production, are governed mostly at national level and it is some how related to political power (Yergin, 2006). On the other hand, however, energy consumption is actually happening largely in urban settings (ie. cities and regencies).

Assuming that the notion of "security" in energy security term is basically a situation of supply side and demand side of an energy system, it is imperative that both sides should be balanced. Policy and decision makers are striving to manage both sides in order to achieve a sense of energy security. The supply side is relatively easier to control by exercising government policies and rules to institutions (i.e. energy and power producer companies) which are compulsory to follow. The demand side, however, is rather difficult to control because the decision on consuming energy is more likely to be individual rather than institutional. Some factors, such as cultural background and values are more influential than government policy in driving decision related to energy consumption (Wijaya & Tezuka, 2013). Therefore, any effort to improve energy security should be developed starting from the end consumer, that is, the local citizen.

In addition to that, energy security is naturally a slippery term and polysemic in nature (Chester, 2010), it can have different meaning and interpretation depending on who is talking. In urban context, citizen perception on the term should be given enough attention because it will have significant impact on how energy security measured, thus how it will be managed. It is clear to say that citizen perspective should be a significant part of an urban energy security measurement.

In the light of this, this research proposes a systematic framework to measure energy security in urban settings with emphasize on citizen perspective and showcase its implementation in a case. The city of Bandung is selected for the case as from 2005 to 2018 its citizen experienced dynamic development spatially (Widiawaty, Dede, & Ismail, 2019) and socio-economically (Badan Pusat Statistik Kota Bandung, 2019) which affect its energy consumption. Results from the urban energy security measurement framework implementation shows that the proposed framework is operationally viable to measuring Bandung's energy security and puts citizen perspective at its core.

2. METHOD

In order to define clearly the scope and stages of the measurement, system approach is adopted to develop the measurement framework. This approach is characterized by top-down hierarchical view of system. Using this approach, the development starts with recognizing the importance of the issue at hand and exploring factors relevan to it. This will become the basis for establishing a context within which the system operates. It is followed by architecting phase where the elements of system are defined hierarchically from general ones down to the specifics.

The framework it self is set into five stages as showed in figure 1. The first stage is establishing the context of the city or regency being studied. It is followed by defining energy security relevant to the context. Afterward, dimension or aspects from the supply side and consumption side are then determined. Next is determining indicators and and metrics. Lastly is calculating energy security. The following sections elaborate each stage by showing how the framework is implemented.

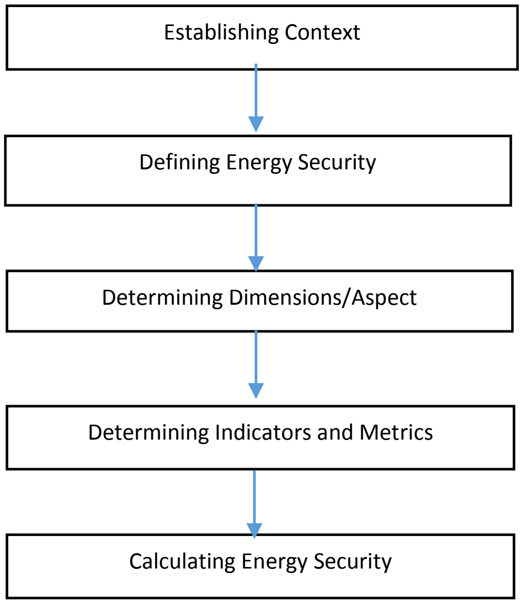

Figure 1. Urban Energy Security Measurement Framewrok

2.1 Establishing Urban Context

Given the fact that energy security issue is inherently contextual (Ang, Choong, & Ng, 2015), therefore, a well rounded urban context is required in the first stage. The context should be able to represent the importance of various factors to energy security issue. In this case, Bandung's data and information which are relevant to urban energy security, such as geo-spatial information, socio-demography, economy, as well as energy consumption, are gathered.

2.1.1 Geo-Spatial and Governance

Bandung (Long 107º36' E, Lat 6º55' S) is the capital city of West Java Province with an area of 16.729,65 Ha. It is situated in the middle of Bandung Basin area at 768 meters above sea level and surrounded by mountains as high as 2.400 meters high. Highest elevation is 1.050 meters in the northern part and lowest elevation is 675 meters in the southern part of the city. It is located about 180 kilometers, southeast of Jakarta as showed in Figure 2.

Figure 2. Bandung City, West Java, Indonesia

Municipality status was given to Bandung in 1906 by the Dutch colonial (Ekajati, Hardjasaputra, Mardiana, & Nasional, 1985) although the area it self has been populated and developed since 1800's. The city comprises of 30 districts or *kecamatan*, as shown in figure 3.

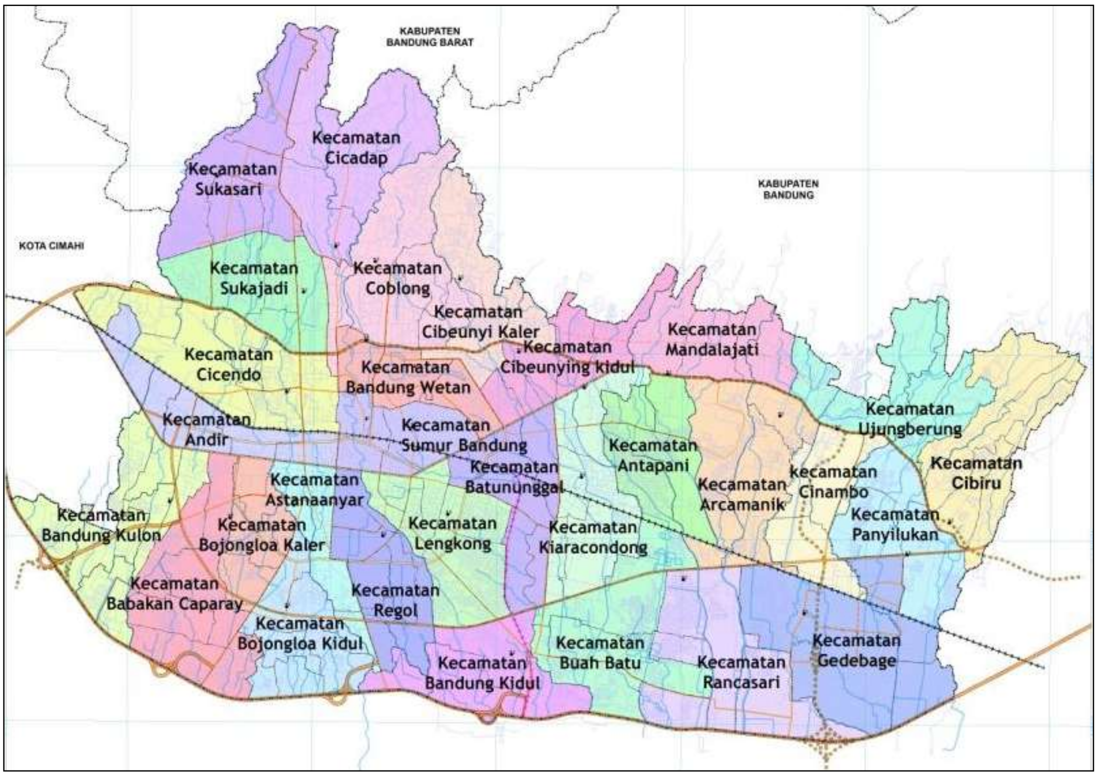

Figure 3. Spatial distribution of districts in Bandung city

2.1.2 Socio Demography

The total population of Bandung city is 2.481.469 (see Table 1) (Government of Bandung City, 2017). The most populated districts are Babakan Ciparay, Bandung Kulon, Kiaracondong and Coblong which respectively consist of more than five percent of the population. Combined, they represent more than twenty percent of population. On the other hand, the least populated district is Cinambo which consist of almost one percent of the population.

Table 1. Population by Districts (Government of Bandung City, 2017)

No	*District*	**Population**	**%**	*No*	*District*	**Population**	**%**
1	Babakan Ciparay	148025	5.97%	11	Buah Batu	95356	3.84%
2	Bandung Kulon	143313	5.78%	12	Bojongloa Kidul	86363	3.48%
3	Kiaracondong	132135	5.32%	13	Sukasari	82012	3.30%
4	Coblong	132002	5.32%	14	Regol	81987	3.30%
5	Bojongloa Kaler	121165	4.88%	15	Ujungberung	75477	3.04%
6	Batununggal	121076	4.88%	16	Rancasari	75469	3.04%
7	Sukajadi	108512	4.37%	17	Antapani	74557	3.00%
8	Cibeunying Kidul	108193	4.36%	18	Lengkong	71637	2.89%
9	Cicendo	99898	4.03%	19	Cibeunying Kaler	71184	2.87%
10	Andir	97693	3.94%	20	Cibiru	70370	2.84%

No	District	Population	%	No	District	Population	%
21	Astanaanyar	68991	2.78%	26	Panyileukan	39339	1.59%
22	Arcamanik	68293	2.75%	27	Gedebage	35910	1.45%
23	Mandalajati	63147	2.54%	28	Sumur Bandung	35903	1.45%
24	Bandung Kidul	59331	2.39%	29	Bandung Wetan	30939	1.25%
25	Cidadap	58426	2.35%	30	Cinambo	24766	0.99%
					Total	**2481469**	100%

The population of the city is characterized by large portion of young citizen at the age between 15 to 34 years old. They represent around thirty percent of the city population. Age 15 to 19 years old is the age of primary education at high school level while 19 to approximately 25 years old is the age for secondary education (i.e. college or university education). Age 25 to 34 years old is the age of fresh graduate and early career level. Figure 4 shows the population profile.

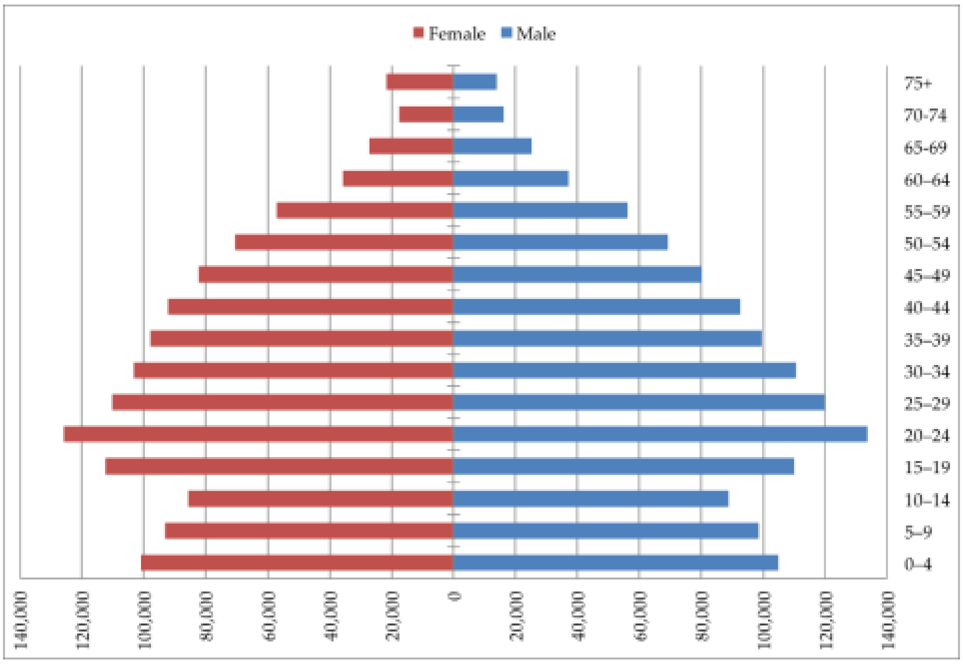

Figure 4. Bandung City Population Profile

2.1.3 Economy

The average monthly spending per capita in Bandung is Rp. 1.433.908 (Badan Pusat Statistik Kota Bandung, 2019). Based on the categorization of expenditure used by the local government, more than forty-four percent citizen of Bandung are in the highest category. This means that each citizen in this class spend more than Rp. 1.000.000 in a month. On the other hand, there is less than two percent of citizen spends Rp. 200.000 to Rp. 299.999 in a month. Figure 5 shows the proportion of population by expenditure classification.

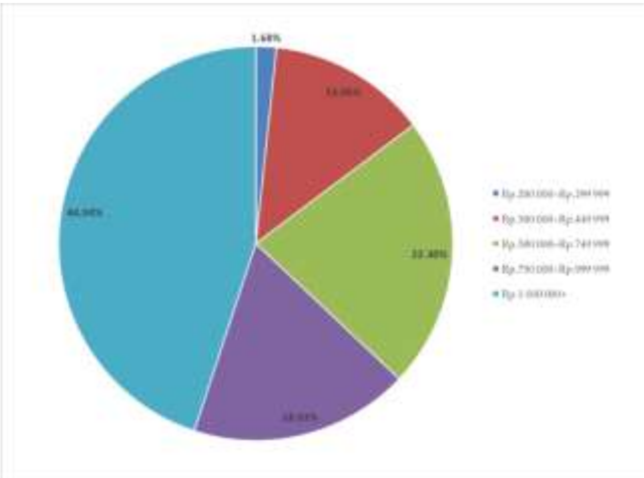

Figure 5. Proportion of Population by Expenditure Class

2.1.4 Energy Consumption

Two sectors are dominating the energy consumption; household and transportation. In term of electricity, household is the largest consumer in both of number and energy used. In 2016, there are 772.062 connected household customers and 1.588 Megawatt-hours consumed by households (Badan Pusat Statistik Kota Bandung, 2017). Transportation is dominating the fossil fuel market (Premium and Solar) with 545.558 Kiloliters of Premium and 109.377 Kiloliters of Solar are sold in the city in 2015 (Saaty & Vargas, 2012).

2.2 Defining Energy Security

The meaning of energy security is ambiguous as different groups of people perceived the term differently (Chester, 2010). This may due to the various interaction people have with energy and various impact it brings to their lives. In the light of this, a working definition of energy security for urban context at hand is needed and therefore it should be conceptualized. The conception can be done by systematically reviewing local government documents related to energy policy and by interviewing two experts.

In order to determine a working definition of energy security the following documents and literatures are reviewed; Local Regulation of Bandung City No. 18 Year 2012, Local Regulation of Jawa Barat Province No. 2 Year 2019 about West Java Provincial Energy Plan (RUED-P), Hikam (2014), and Sugiyono (2016). The review process produced a summary of issues and topics stated explicitly in the documents which indicates concerns or institutional standings on the issue of energy security. The summary is shared and discussed with experts to produce the following conception of energy security: "*A condition where energy sources (except coal) and electricity are available sufficiently, in good quality, at appropriate price to support Bandung city development with consideration on sustainable development principle*". This definition of energy security will be the basis for the following steps.

2.3 Determining Dimensions

The literatures provide many dimensions, factors or aspects that can be used to assess energy security along with hundreds of metrics of measurement. The 4As, availability, accessibility, affordability, acceptability (Asia Pasific Energy Research Centre, 2007) is a popular example of dimensions considered in energy security assessment, in addition to that, there are more specific factors that can be considered, such as from (Cherp & Jewell, 2014; Winzer, 2012). However, the dimensions considered in this research should be principally based on the definition of energy security produced in the previous stage. From there, the dimensions are then selected in three steps which are explained in the next paragraphs.

First, subjective filtering process by experts. This is to shortlist some important dimensions inline with the definition and relevant to the context within hand. Second, dimensions selection by experts. It is important to emphasis that the experts at this stage are locals which also represent citizen perspective. Here, the list is prioritized and only few dimensions that are deemed very important and relevant to citizen are then selected for further process. A prioritization method, Analytical Hierarchy Process or AHP (Gupta, 2008), was deployed for the selection process. It resulted in a set of prioritized dimensions presented in Table 2 sorted by weight. Three dimensions have much more weight than the others. They are Availability, Affordability, and Quality. Together they account for 76% of the overall weight. These dimensions are selected for further weighting by general citizen. The weighting will be based on the importance value of the dimension to citizen.

Third, general citizen is invited to give their opinion on these dimensions through questionnaire measuring their importance. This stage is actually the stage that reflects citizen perspective towards energy security. Therefore, it is crucial for the research to represent all member of citizen as a whole in a balance manner. To do this, following setups are applied for the surveys; (a). The number of citizen participating in the surveys are proportional to the number of person within the sub-area of the city (i.e. districts). This is because the number of citizen in some sub-areas can be larger than others, therefore to represent the city fairly, more populated sub-areas should be sampled more than less-dense area. (b). The proportion of surveyed citizen should represent the socio-demographic feature of the city. Since the output of the survey will determine how the city perceived energy security therefore citizen from all socio-demographic classes should be considered. It is an important point of view to analize the result for each socio demographic classes as each classes has its own perception on the importance of energy for their life thus energy security as this is consistent with what Chester (2010) asserted. However, in this paper the purpose of this classification is to find out a set of perception of energy security which can represent the view of citizen in general. Analizing the result based on socio demographic classes will be a follow up of this research (c). Considering the previous reason, the proportion of surveyed citizen should also represent the economic classes in the city.

Table 2. Dimensions Priority

Dimension	Weight	Priority Rank
Availability	0.31	1
Affordability	0.27	2
Quality	0.18	3
Policy	0.08	4
Environment Sustainability	0.07	5
New and Renewable Energy	0.05	6
Vulnerability	0.04	7

CRI: 0,07

A survey using rating scale technique was deployed to collect 400 citizen responses from all over Bandung city. In order to make sure an appropriate representation of more-populated districts and less-populated ones, the survey was distributed proportionally to the number of citizen living in respective district. Considering the demographic profile of Bandung, the survey is specifically targeted to acquire about fifty percent young adult respondents from 15 to 34 years old.

The survey result shows interesting results. The dimension rank is the same where Availability first then followed by Affordability and Quality. However, the weight gap from Availability to Affordability and Availability to Quality is larger than expected. Weight of Availability is 0.74 while Affordability is 0.10 and Quality is 0.06.

The survey also reveals that electricity is regarded as the most important energy while oil products (gasoline/solar) and liquefied petroleum gas (LPG) are respectively second and third. In order to showcase the framework deeply and provide more insights, this paper will focus only on electricity for further elaboration.

2.4 Determining Indicators and Metrics

Once dimensions are selected and prioritized, indicators and metrics of measurement are determined. In this stage, we review again government documents and the literatures. Some local governments may already have indicators and metrics in place whether it is by their own judgment or derived from higher level government policy.

Initial indicators and metrics for the three dimensions are collected from Winzer (2012); Vivoda (2010); Sovacool and Saunders (2014); Cherp (2012); Kruyt, van Vuuren, de Vries, and Groenenberg (2009); Prambudia and Nakano (2012b); Chen and Chen (2015); Prambudia and Nakano (2012a). They are then selected through forum group discussions with experts. The selection is based on two criteria; simplicity and data availability. Simplicity is considered because general citizen may be lacking of analytical knowledge to assess complex metrics more over they may not have ample time to do so. It is assumed that by using simple metrics the result will be more meaningful and make sense to general citizen. Availability of data is another criterion considered because some data could be too difficult to be acquired thus would require more resources than the research could provide.

The following Table 3 presents indicators that are used to measure Availability, Affordability and Quality of electricity in Bandung city.

Table 3. Dimension and Indicators

Dimension	Indicators
Availability	Supply-Demand Ratio
	Production Excess-Demand Ratio
Affordability	Portion of energy cost in expenditure
Quality	Service Level

Mathematically, Supply Demand Ratio (SDR) can be expressed in percentage and calculated as follows:

$$\mathrm{SDR} = \frac{\mathrm{P}}{\mathrm{D}}, \tag{1}$$

where,
P = Electricity Production (KWh)
D = Electriciy Demand (KWh),
here, demand is the amount of electricity sold to consumer.

Production-Excess/Demand Ratio (PEDR) is expressed in percentage and calculated by electricity production surplus divided by demand. Production surplus is calculated by subtracting production amount with demand. Mathematically it is expressed as follow:

$$\mathrm{PEDR} = \frac{\mathrm{P}-\mathrm{D}^{s}}{\mathrm{D}}, \tag{2}$$

where,
P = Electricity Production (KWh)
D = Electricity Demand (KWh),
D^S = Electricity Demand including shrinkage (KWh),

in this metric, demand is the amount of electricity sold to consumer added by the amount of distributional shrinkage. It is expressed as follow:

$$\mathrm{D}^{S} = \mathrm{J} + \mathrm{S}, \tag{3}$$

where,
J = Sold electricity (KWh)
S = Shrinkage (KWh)

The affordability dimension is measured by the Portion of Energy Cost in Expenditure (PECX). It is expressed as follow:

$$\mathrm{PECX} = \frac{EC}{X}, \tag{4}$$

where,
EC= Monthly electricity cost per capita
X = Monthly expenditure per capita

Quality dimension is measured by the Service Level (SL) in a year. Blackout occurrence is the only variable in this metric. A blackout is considered if it is lasted for more than 3 hours.

$$\mathrm{SL} = 1 - \frac{BO}{12}, \tag{5}$$

where,
BO = Black out occurrence in a year

2.5 Calculating Energy Security

Level of energy security is expressed in the values of metrics. Data relevant to metrics are collected and inputted to the metrics to calculate energy security values. In order to analyze consistently, a complete set of metrics data from the same period of time is needed. In this case, complete set of Bandung's data is available only in the year of 2015, therefore the calculation of energy security is for that year only. Afterwards, a classification of energy security status then established based on the values. In the following, the data and its calculation are explained.

Total electricity production in 2015 was 4.374.539.408 KWh therefore the average monthly production rate is 364.544.950,7 KWh/Month. On the other hand, electricity sold in 2015 was 4.091.649.358 KWh at the rate of 340.970.779,8 KWh/Month. Shrinkage in 2015 is recorded at 226.198.916 KWh therefore monthly shrinkage is at 18.849.909.7 KWh/Month.

There were several electricity price adjustments in 2015. An average value of all price adjustment is used for this research. The prices considered are prices of voltage class of household customers only. The prices are averaged to Rp. 1.424,03/KWh. The average monthly electricity cost per capita in Bandung is at Rp. 195.667,92.

There is one blackout recorded in 2015. It happened in the month of April and lasted for more than 17 hours. Several distribution areas within Ujung Berung district were affected. The blackout was due to an exploded power transformer.

Considering citizen opinion which put different importance weight to each of the dimension, therefore the partial score is calculated further by the weight. Table 4 present the calculation results of each metric.

Table 4. Energy Security Score

Metric	Value	Reference Value	Unweighted Score	Citizen's Importance Weight	Weighted Score
SDR	106.9%	120%	0.89	0.76	0.78
PEDR	1.3%	10%	0.13		
PECX	13.6%	10%	1.36	0.18	0.25
SL	91.7%	100%	0.92	0.06	0.06
		Total Score	***3.30***		***1.08***

A classification of energy security status is applied by considering these four status; High, Medium High, Medium Low, and Low. High is when the total score is within the range of 3.00 to 4.00, Medium High when it is between 2.00 to 2.99, and respectively Medium Low is between 1.00 to 1.99 and Low is between 0.00 to 0.99. The range gap of each class is equal to 1.00. Table 5 presents the status.

Table 5. Energy Security Status

Total Score Range	Energy Security Status
3.00 - 4.00	High
2.00 - 2.99	Medium High
1.00 - 1.99	Medium Low
0.00 - 0.99	Low

3. RESULT AND DISCUSSION

Implementation result shows that based on citizen perspective, Bandung's energy security in 2015 is at 1.08 out of 4.00. With this result, Bandung's energy security is in the Medium Low status. However, the result is quite different if no perspective is considered. The unweighted score calculation is resulted in High status with score of 3.30. This is due to large portion of importance is being placed by citizen to Availability dimension.

This striking difference between weighted and unweighted score corroborates the claim that energy security is perceived differently by different subject (Chester, 2010). Hence, the question of "who" (Cherp & Jewell, 2014) is highly relevant in measuring energy security in urban setting. This may lead to a suggestion that participatory approach could be useful to emphasize the acceptance of the measurement.

Considering that participating respondents are general citizen which has very limited knowledge about energy in general and energy security specifically, the research aims to present energy security in simple terms and easily understood by city wide population. Therefore, this research takes only the most weighted dimensions, indicators and metrics into consideration and put more effort on making sure that the participating citizen can understand fully each dimension subjected to their opinion. On one hand, this may increase the understandability of the measurement but on the other hand it undermines the comprehensiveness of the measurement. In this regards, the framework it self is not limiting the number of dimension or indicator and metric to be taken into account. A research that seeks comprehensiveness of the measurements may consider all the dimensions selected by their experts as subject to citizen opinion. In idealistic setting, such research might consider many more dimensions as provided in Winzer (2012) and Sovacool and Saunders (2014).

It can be noticed that energy security indicators are interrelated. This means that performance of an indicator can be influenced by performance of other indicators. Provided enough indicators, there may be a reciprocal influence via other indicators. For example, the Quality dimension in this research is measured based on the amount of black-out. Black out is basically a status which electricity is not available for use. Therefore, the occurrence of black out it self is somehow influencing Availability dimensions, both in term of perception and also technical. If taken into account, the interrelation among indicators may further improve the accuracy of urban energy security measurement. However, this requires a different approach on how urban energy security should be evaluated. Integrated method and approach such as presented by Bassi (2010) and (Winzer, 2012) are useful to capture the dynamics of urban energy security.

During the survey, several women respondents in eastern districts says cooking as the most important activities for them, however they do not choose LPG as the most important energy source, instead, they choose electricity. This is because in order to cook they need water and to get water from underground reservoir they need their electric pump turned on. This observation, although it will need further investigation, may be attributed to Bandung's reliance on underground water (Wulandari, Abdullah, Al Rasyid, & Kristyanto, 2017). This may be the cause of why electric water pump is ubiquitous in this city and seems to become a requirement for a house to function properly. It is also inline with the notion that energy requirement is getting higher once water becoming more difficult to get (Rygaard, Binning, & Albrechtsen, 2011). From another view, this can also be related to Bandung's increased economic development which leads to higher energy service ladder (Sovacool, 2011) in the area.

4. CONCLUSION

A systematic framework to measure urban energy security has been presented and implemented in a case. The framework consists of five stages which define the scope of measurement including subjects, dimensions, metrics, data, valuing and scoring techniques. Being systematic, the process follows the stages consecutively from the first to fifth stage as the outputs from former stage are being used by the later stages. The implementation case shows that the framework is operationally viable and it can capture the significance of citizen perspective on urban energy security evaluation.

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